Equal annoyance contours for infrasonic frequencies

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EQUAL ANNOYANCE CONTOURS FOR INFRASONIC FREQUENCIES

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INTRODUCTION

Infrasound, at pressure levels that can be heard, is quite common in our daily surroundings, and may cause considerable annoyance. A few countries have introduced measurement procedures and hygienic limits, but there has been a deplorable lack of experimental facts on which to base these.

For audiosound the agreement between annoyance and loudness is usually so good that dB(A) and similar measures developed from loudness investigations can be used as an estimate of the annoyance effect. It might therefore seem a possibility to use the equal loudness curves already described for the infrasound region (1, 2, 3) as a base for an extension downward of existing weighting curves. However, the close relation between annoyance and loudness found at higher frequencies may not exist in the infrasound region, because very low frequencies are perceived as a throbbing sound instead of a tone, and this may have an influence on the annoyance experience.

The aim of the present project has been to establish equal annoyance contours in the frequency range 4-31.5 Hz.

METHOD

Subjects

Eighteen students participated (15 men and 3 women; age range: 20-25). All were paid volunteers, and all were familiar with infrasound stimuli from their participation in our work on equal loudness curves for the infrasonic range. An audiometric test ensured normal hearing.

Sound conditions

The following 18 sound exposure conditions were used: 4 Hz at 120 and 124 dB; 8 Hz at 109, 114, 119 and 124 dB; 16 Hz at 95, 102, 109 and 116 dB; 31.5 Hz at 75, 84, 93 and 102 dB; 1 kHz octave filtered pink noise at 20, 40, 60 and 80 dB.

Apparatus
The experiments were performed in a 16 cubic metre pressure chamber. The infrasound was emitted via 16 electrodynamic loudspeakers driven by a B & K 2712 power amplifier. The 1000 Hz noise was emitted via an equalized Hi-Fi sound reproduction system with the loudspeaker placed 140 cm from the subject. An HP 21MX computer controlled the experiments.

Experimental design
The design was an 18 x 18 latin square that balanced both order and carry-over effects. Each subject was exposed to only one stimulus a day for 18 days and at the same hour every day.

Procedure
A session lasted 20 minutes. During this period the subject was alone in the test chamber. He was supplied with two newspapers and instructed to read till the end of the session. After 5 minutes of silence the sound stimulus was presented for 15 minutes. After the exposure the subject indicated on a scale the degree of annoyance that he would probably feel, if his neighbour produced the same type of sound for two hours. The scale was a 150 mm long horizontal line, the ends of which were labelled respectively "not at all annoying" and "very annoying".

RESULTS

Degree of annoyance was measured in mm, and means for each of the 18 stimuli were calculated. The relationship between sound pressure level and mean annoyance rating is linear for the infrasonic frequencies (coefficients of correlation higher than 0.99). The means are presented graphically in Figure 1 together with the regression lines for the infrasonic frequencies.

A horizontal line drawn from a 1000 Hz point in Figure 1 will intersect the regression lines at sound pressure levels where the respective infrasonic frequency causes the same annoyance rating as the 1000 Hz noise. Lines were drawn from each of the four 1000 Hz points and the equal annoyance contours in Figure 2 were obtanied.

The equal annoyance curves demonstrate the not very surprising fact that the lower the frequency the greater the sound pressure must be to cause a given amount of annoyance. Compared with 1000 Hz the curves lie much closer in the infrasonic range. This change is already seen at 31.5 Hz, but becomes even more pronounced with decreasing frequency.

DISCUSSION

The closeness of the curves in the infrasonic region implies that relatively small changes in sound pressure may cause large changes in annoyance. From an environmental point of view this is important because a modest reduction in sound pressure will in some cases be enough to alleviate annoyance caused by infrasonic noise. It also means that accuracy is crucial when measuring infrasound and that specific demands must be made on the measuring equipment.

Several investigations have shown that dB(A) measures are unsatisfactory for the assessment of annoyance from sounds containing a considerable amount of low frequency energy. The disagreement between dB(A) values and ratings of annoyance has often been interpreted as a difference between the experience of loudness and the experience of annoyance. However, the present equal annoyance curves are remarkably similar to the equal loudness curves (2, 3) and the relation between loudness and annoyance seems to hold for low and infrasonic frequencies too.

Both the equal annoyance and the equal loudness curves have slopes close to 12 dB per octave and this slope is recommended for a possible weighting curve for infrasound.

PROJECTED EXPERIMENTS

Ongoing and future experiments deal with annoyance from non-sinusoidal infrasonic noise and combinations of audio and infrasonic noise. The significance of the exposure time is also investigated.

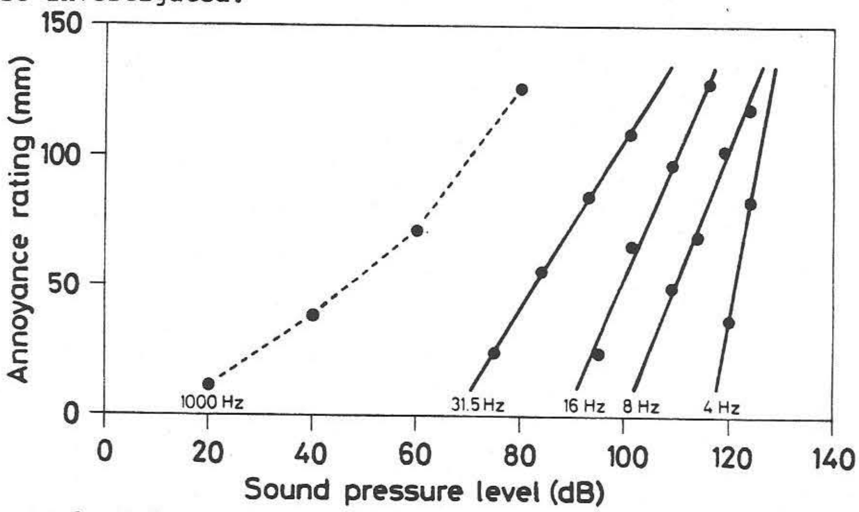

Figure 1. Relation between sound pressure level and annoyance rating. The filled circles represent the means for each stimulus, and the lines are regression lines for each infrasonic frequency.

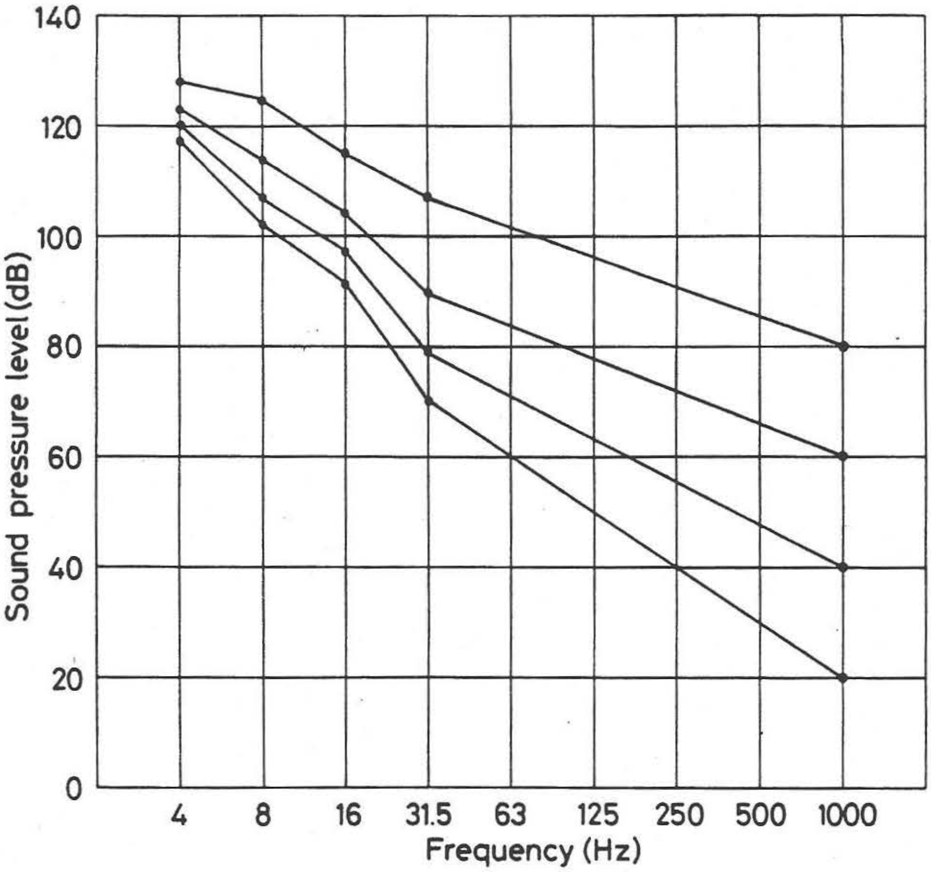

Figure 2. Equal annoyance contours.

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